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RADIONUCLIDE STUDY - PICKERING NGS B POST-OPERATIONAL STUDY, 1987

Report No 88-201-K

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ABSTRACT

The results of a radionuclide study conducted as part of the 1987 Pickering NGS B postoperational studies are presented. The objective was to determine whether there were areas of increased accumulation of ^{134}Cs, ^{137}Cs and ^{60}Co in the sediment around Pickering NGS. The distributions of the three radionuclides were correlated with each other suggesting a similar source and similar variables affecting their distributions. Highest levels of all three radionuclides were found immediately to the west of the Pickering NGS A discharge. The distributions of ^{134}Cs, ^{137}Cs and ^{60}Co were source related and decreased with distance from Pickering NGS. The levels of these three radionuclides reported for the study area by Health and Safety Division of Ontario Hydro were within the ranges obtained during the present study. The levels of ^{134}Cs, ^{137}Cs and ^{60}Co were also measured in smallmouth bass (whole) collected from the Pickering NGS B study area. Only ^{137}Cs was detected and was present in levels typical of Lake Ontario fish and comparable to levels recorded by Health and Safety for trout from the Pickering NGS B study area. It is suggested that the presence of Pickering NGS has not resulted in substantial increases in smallmouth bass radionuclide levels.

job	file	date	report no.
34-159-401	837.321 PIC	October 7, 1988	88-201-K

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EXECUTIVE SUMMARY

RADIONUCLIDE STUDY - PICKERING NGS B POST-OPERATIONAL STUDY, 1987

J.K. Kwik
Biological Research Section
Chemical Research Department

The results of a radionuclide study conducted as part of the 1987 Pickering NGS postoperational studies are presented. The study was requested by the Environmental Studies and Assessment Department of the Design and Development Division on behalf of the Pickering Engineering Department.

The hypothesis, identified at a workshop held on the Pickering NGS B post-operational studies, is that the concentration of radionuclides in water and the bioaccumulation of radionuclides in fish as a result of chronic release of radionuclides by the station would not pose a threat to human health. The objective of the present study was to determine whether there are areas of accumulation of ^{134}Cs, ^{137}Cs and ^{60}Co in the surface sediment around Pickering NGS. Higher levels of radionuclides in the sediment would be reflected in the benthos leading to bioaccumulation. Smallmouth bass from the study area were also analyzed for ^{134}Cs, ^{137}Cs and ^{60}Co as an indication of bioaccumulation.

Sediment ^{134}Cs, ^{137}Cs, and ^{60}Co levels were highest immediately west of the Pickering NGS A discharge. The three radionuclides were correlated with each other suggesting a similar source and similar variables affecting their distributions.

Depth was the main variable affecting the distribution of the three radionuclides. Their levels decreased with depth suggesting a decline with distance from Pickering NGS.

Thus the distributions of ^{134}Cs, ^{137}Cs and ^{60}Co were source related and decreased with distance from Pickering NGS. As hypothesized, chronic release of low levels of radionuclides into the water resulted in areas of higher accumulation in the sediment around Pickering NGS. However, these areas appear to be limited to the immediate vicinity of the station.

Levels of ^{134}Cs, ^{137}Cs and ^{60}Co reported for the sediment in the study area by Health and Safety Division of Ontario Hydro were within the ranges obtained during the present study.

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Of the three radionuclides, only ^{137}Cs was detected in smallmouth bass (whole fish). Based on the fish which we examined, levels of these radionuclides in fish from the Pickering area were similar to those in fish from other parts of Lake Ontario and comparable to levels recorded by Health and Safety for trout from the Pickering NGS B study area. It is suggested that the presence of Pickering NGS has not resulted in substantial increases in smallmouth bass radionuclide levels.

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RADIONUCLIDE STUDY - PICKERING NGS B
POST-OPERATIONAL STUDY, 1987

1.0 INTRODUCTION

Pickering NGS B is a nuclear station consisting of four CANDU powered 540 MW units (units 5-8) located on the north shore of Lake Ontario at Pickering, Ontario. The station is situated on the east side of Pickering NGS A which also consists of four CANDU powered 540 MW units (units 1-4). The two stations have a common surface condenser cooling water intake. Pickering NGS B discharges its cooling water to the east of the development and Pickering NGS A discharges to the west.

Chronic low levels of radioactive substances are discharged at all nuclear stations. Gamma radionuclides released include ^{134}Cs, ^{137}Cs, and ^{60}Co. Derived emission limits (DEL) for gross gamma and beta radionuclides for water, set to limit the exposure of radioactive substances to the public, is 2.8 Bq/month for Pickering NGS B and 1.4 Bq/month for Pickering NGS A (RMEP-IR-07000-16). The operating target for radiological emissions at Ontario Hydro nuclear generating stations is 1% or less of the DEL. In 1987 the actual discharge of gross gamma and beta radionuclides by water was 0.05% of its DEL at Pickering NGS B and 0.07% of its DEL at Pickering NGS A.

A workshop was held in 1985 with the purpose of designing the Pickering NGS B post-operational studies. The objectives of the studies included in the Pickering NGS B post-operational program were based on hypotheses identified at this workshop. For radionuclides it was suggested that the continuous low level releases of radioactive substances by the station would result in increased concentrations in the waters surrounding the station (Greig et al 1986). Sorption of the radionuclides to suspended sediments followed by the settling of these particles would then result in increased levels in the sediment around the station. The higher levels of radionuclides in the water would be reflected in the plankton while higher levels in the sediment would be reflected in the benthos, leading to bioaccumulation. The hypothesis was that neither the concentration of radionuclides in drinking water nor the bioaccumulation of radionuclides in fish would pose a threat to human health.

This study is part of the Pickering NGS B post-operational aquatic program and was requested by the Environmental Studies and Assessment Department of the Design and Development Division on behalf of the Pickering Engineering Department.

The objective of this study was to determine whether there are areas of accumulation of ^{134}Cs, ^{137}Cs and ^{60}Co in the surface sediment around Pickering NGS. In addition, smallmouth bass from the study area were analyzed for the above radionuclides as an indication of bioaccumulation.

2.0 METHODS

Sediment samples for radionuclide analyses were collected in September and October of 1987.

Surface sediment samples were collected by scooping 1-litre nalgene containers through the top 5 cm layer of sediment. The sampling design as recommended by the Environmental Studies and Assessment Department of Design & Development and was based on proportional allocation of sites according to the relative size of substrate strata identified during substrate mapping in 1985 (Weninger 1986). The sampling locations are presented in Figure 1. The study covered an area 5.5 km along shore and 2.5 km offshore.

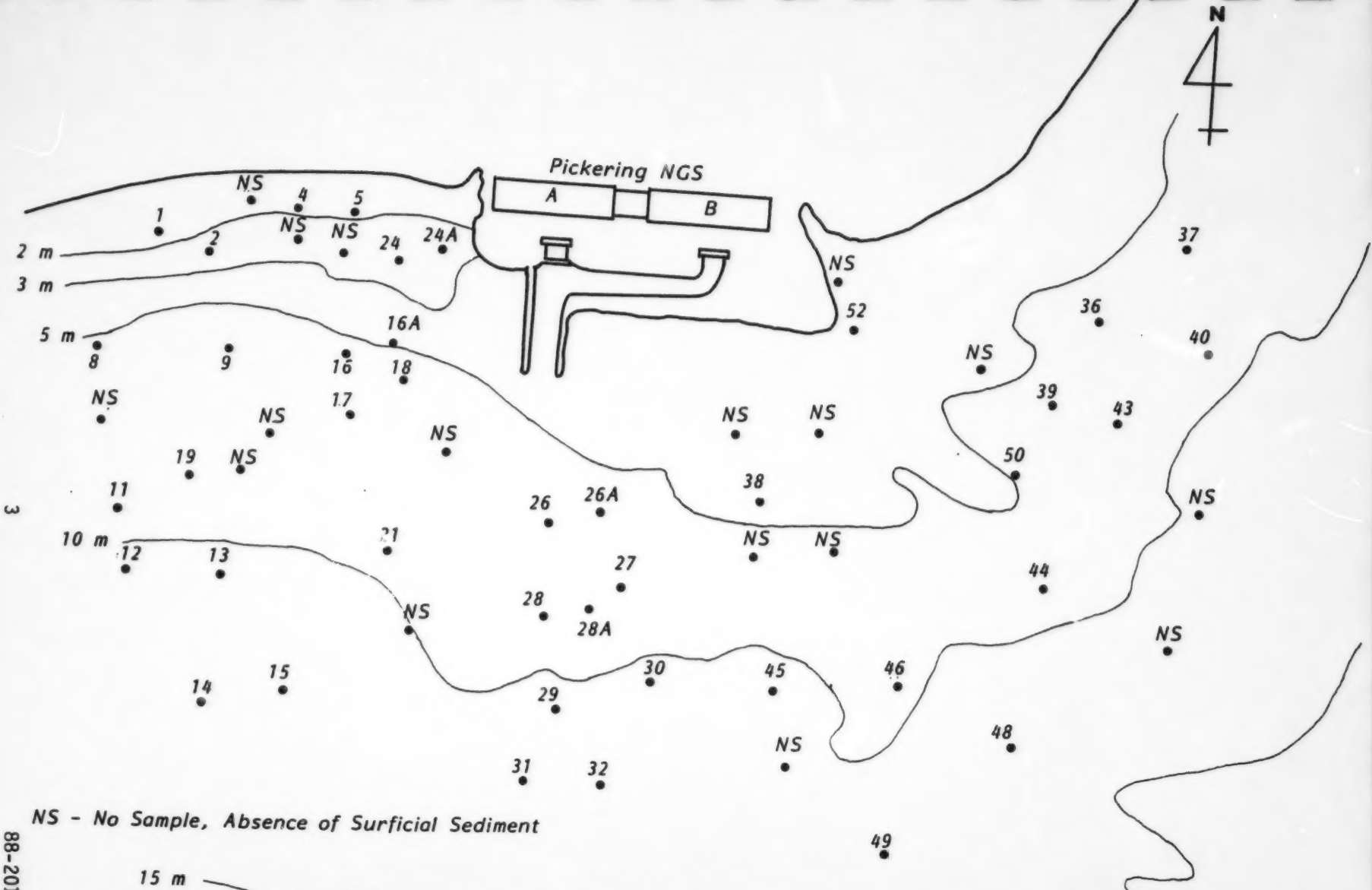
Based on the 1985 sediment map (Weninger 1986), 54 locations with appropriate substrate (sand, silt) were selected. However, several of these locations did not have appropriate sediment to sample from and samples were only obtained from 43 locations. A sample collected from location 51 in the Pickering NGS B discharge was lost and only 42 samples were analyzed for ^{134}Cs, ^{137}Cs and ^{60}Co.

The sediment samples were frozen immediately following collection. Following a thawing period the samples were oven dried at 105°C for a minimum of 24 hours and weighed. Radioactivity counts were then taken over a 24-hour period with an APTEC low background Hyper-pure Germanium detector (15% efficiency). The detector was coupled to a computerized multichannel analyzer (PCMCA) and gamma radionuclide activities were determined using a computerized program (PCGAM). Radiological analyses were performed by the Analytical Services Section of Ontario Hydro Research Division. Results are expressed as Bq/kg sediment dry weight.

In addition to the radionuclide analyses, the sediments were subjected to sediment particle size analyses and organic content determination. Particle size was determined by the wet sieve method (Folk, 1986) in which the samples are passed through a series of sieves ranging from 1.5 to 0.038 mm. The portions collected on each sieve are then oven dried at 105°C for at least 24 hours and weighed. Organic content was determined by loss on ignition following an ashing period of 1-hour at 550°C. The portion lost on ignition was accepted as the organic portion.

Smallmouth bass for radionuclide analyses were taken from the gill net catches taken during the monthly fish surveys conducted as part of the Pickering NGS B post-operational study. A single sample of fish collected at non-discharge locations in 1986 and three samples of fish collected at the discharges in 1987 were analyzed for ^{134}Cs, ^{137}Cs and ^{60}Co.

The smallmouth bass (whole fish) samples were ground up in a blender and freeze dried in a Vistis Freezemobile II for a minimum of 48 hours. Radionuclide determinations of the fish samples were carried out using the same methods and equipment used for the sediment radionuclide analyses. Results are presented as Bq/kg wet weight.



NS - No Sample, Absence of Surficial Sediment

FIGURE 1

SEDIMENT SAMPLING LOCATIONS FOR CESIUM-134, CESIUM-137 AND COBALT-60 ANALYSIS, PICKERING NGS 'B' POST-OPERATIONAL STUDY, 1987

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2.1 Data Analysis

To determine variables which had significant effects on the distribution of the radionuclides, the data were subjected to Correlation Analysis and Stepwise Multiple Regression Analysis (SPSS/PC+). Variables included in the analyses were: depth, location (Loran coordinates), per cent silt content (from particle size analysis), and per cent organic content. Significance was determined at the $P<0.05$ level.

3.0 RESULTS

The levels of ^{134}Cs, ^{137}Cs and ^{60}Co as well as the silt and organic content of the samples are presented in Table 1. The mean level of ^{134}Cs in the surface sediments of the study area was 1.3 Bq/kg (± 1.5 Bq/kg) and individual counts ranged from 0.1 to 7.8 Bq/kg (Table 2). Highest levels were found immediately west of the Pickering NGS A discharge (Figure 2). An area of intermediate levels occurred just north of the area of highest accumulation and stretched around Pickering NGS to the western border of the study area. Intermediate levels were also found in the northwestern end of the study area and at a location approximately 2.2 km offshore from the Pickering NGS B discharge.

The mean level of ^{137}Cs was 7.8 Bq/kg (±5.3 Bq/kg). Individual values ranged widely from a low of 2.3 to a high of 30.0 Bq/kg with highest levels found immediately west of the Pickering NGS A discharge (Figure 3). Intermediate levels were found at a location 0.9 km offshore from the Pickering NGS A discharge and in a narrow band along the 10 metre depth contour in the eastern portion of the study area.

^{60}Co occurred at a mean level of 1.3 Bq/kg (± 0.9 Bq/kg). It was detected at levels ranging from 0.1 to 3.6 Bq/kg. Higher accumulation of this radionuclide was found immediately west of the Pickering NGS A discharge (Figure 4). This area of higher activity extended about 1.0 km offshore. A smaller area of higher activity was detected in the centre of the study area, approximately 1.5 km north of the stations.

Correlation analyses indicated that the three radionuclides were significantly correlated with each other. ^{134}Cs and ^{137}Cs were highly correlated ($R = .89$) while ^{60}Co was not as highly correlated with ^{134}Cs ($R = .43$) or ^{137}Cs ($R = .37$).

Stepwise multiple regression analysis indicated that the distribution of ^{134}Cs was significantly related to depth, per cent silt and the offshore distance, in that order. Together these three variables accounted for 52% of the variation in the distribution of this radionuclide. ^{134}Cs decreased with depth and silt content, and with distance from shore.

^{137}Cs levels were significantly related primarily to depth followed by per cent silt. These two variables accounted for 35% of the variation in the distribution of ^{137}Cs. The levels of this radionuclide also decreased with depth and silt content.

The distribution of ^{60}Co was significantly affected mainly by depth, followed by the offshore distance. These two variables accounted for 32% of the variation of ^{60}Co in the study area. The levels of this radionuclide decreased with depth and distance from shore.

Smallmouth bass levels of ^{134}Cs and ^{60}Co were below their detection limits of 0.2 Bq/kg in all four samples (Table 3). ^{137}Cs was measured at 1.3 Bq/kg in the 1986 non-discharge sample and at a mean level of 0.3 Bq/kg (± 0.03 Bq/kg) in the 1987 discharge samples.

TABLE 1

PICKERING NGS B 1987 - SEDIMENT LEVELS OF CS-134, CS-137, CO-60, SILT AND ORGANIC CONTENT

LOCATION	Cesium-134 Bq	Cesium-137 Bq	Cobalt-60 Bq	% SILT	%ORGANIC CONTENT
1	1.37	7.03	1.81	40.0	0.7
2	2.96	7.40	1.44	42.9	0.6
4	4.81	19.24	2.15	20.0	1.3
5	4.81	21.83	3.55	4.1	1.1
8	<0.20	3.89	0.81	61.4	0.8
9	<0.20	3.44	1.22	47.0	1.0
11	0.89	4.14	1.04	18.9	0.7
12	1.55	5.77	2.00	17.8	0.9
13	1.11	7.77	1.85	38.7	1.7
14	0.89	5.55	0.93	22.2	0.9
15	0.67	4.81	0.52	7.8	0.8
16	0.93	7.18	2.44	73.1	1.1
16A	1.92	12.58	3.11	5.4	0.5
17	0.93	3.74	1.11	21.7	1.1
18	0.52	4.81	2.66	65.5	2.0
19	<0.20	2.33	0.89	12.9	1.9
21	1.11	10.36	0.41	69.1	1.1
24	7.77	30.01	2.22	7.4	0.5
24A	1.78	8.88	1.85	56.2	2.7
26	0.81	5.18	1.37	39.4	0.9
26A	1.07	3.70	0.67	6.5	1.0
27	0.56	6.44	3.44	42.1	2.8
28	0.67	4.29	0.93	53.4	2.8
28A	0.78	8.14	2.52	30.8	2.2
29	0.93	5.92	0.93	2.5	1.1
30	1.00	5.55	0.93	9.5	1.4
31	0.96	4.07	0.70	0.8	0.8
32	0.96	8.51	0.67	1.5	1.6
36	0.70	6.29	0.67	10.2	2.4
37	<0.20	3.07	1.11	38.7	4.3
38	0.93	5.55	1.22	22.1	1.7
39	1.48	6.44	1.48	0.7	1.3
40	1.30	11.10	1.04	2.8	1.1
43	1.59	13.69	<0.20	2.9	1.7
44	<0.20	3.70	<0.20	0.4	0.7
45	<0.20	6.85	1.15	7.6	1.7
46	1.81	11.84	<0.20	5.3	1.3
48	<0.20	3.44	<0.20	0.3	0.6
49	<0.20	9.07	<0.20	0.5	0.9
50	<0.20	10.10	1.18	1.0	1.0
52	1.85	6.59	1.85	2.3	1.4

TABLE 2
SUMMARY OF SEDIMENT RADIONUCLIDE ANALYSES
PICKERING NGS B, 1987

	MEAN	STANDARD DEVIATION	MINIMUM	MAXIMUM
	Bq/kg			
CESIUM-134	1.3	1.5	<0.2	7.8
CESIUM-137	7.8	5.3	2.3	30.0
COBALT-60	1.3	0.9	<0.2	3.6

TABLE 3
RADIONUCLIDE LEVELS IN SMALLMOUTH BASS
FROM THE PICKERING NGS B STUDY AREA

		DISCHARGE	NON-DISCHARGE
		Bq/kg wet weight	
CESIUM-134	1986	NS	<0.2
	1987	<0.2	NS
CESIUM-137	1986	NS	1.5
	1987	0.3+0.03	NS
COBALT-60	1986	NS	<0.2
	1987	<0.2	NS

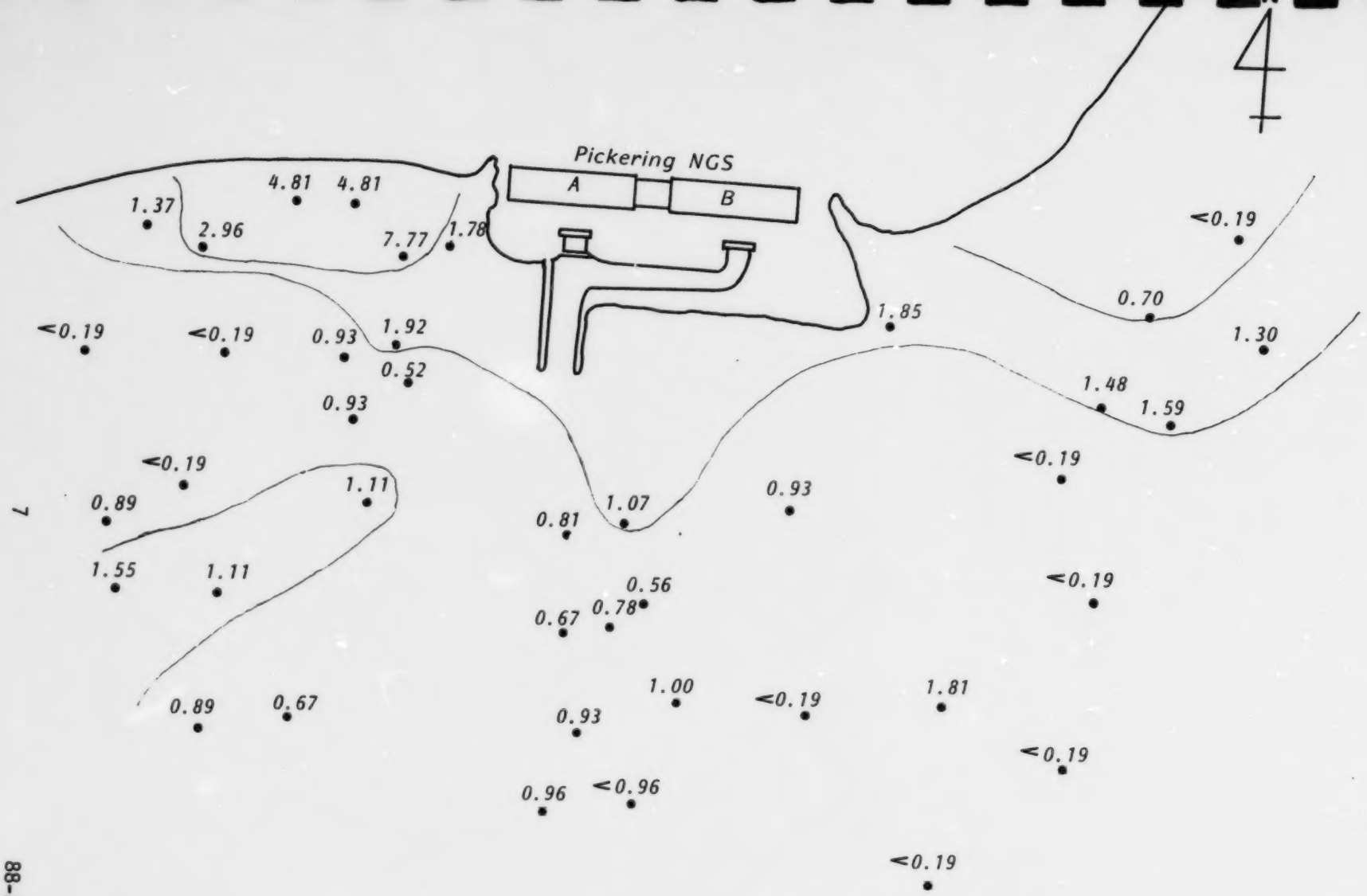

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FIGURE 2
DISTRIBUTION OF CESIUM-134 (Bq/kg) IN THE SEDIMENT
AROUND PICKERING NGS,
PICKERING NGS B POST-OPERATIONAL STUDY, 1987

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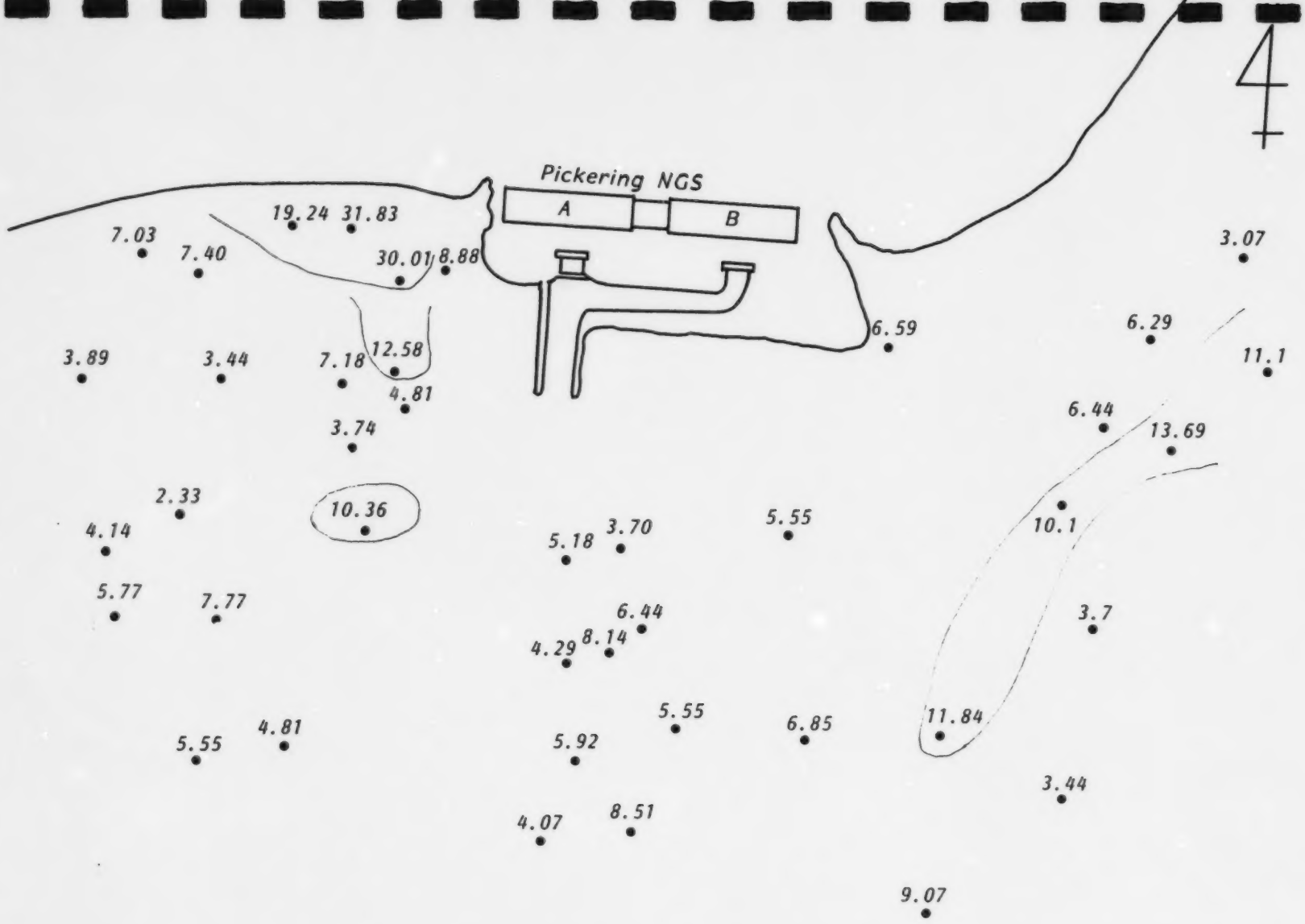

FIGURE 3

DISTRIBUTION OF CESIUM-137 (Bq/kg) IN THE SEDIMENT AROUND PICKERING NGS, PICKERING NGS B POST-OPERATIONAL STUDY, 1987

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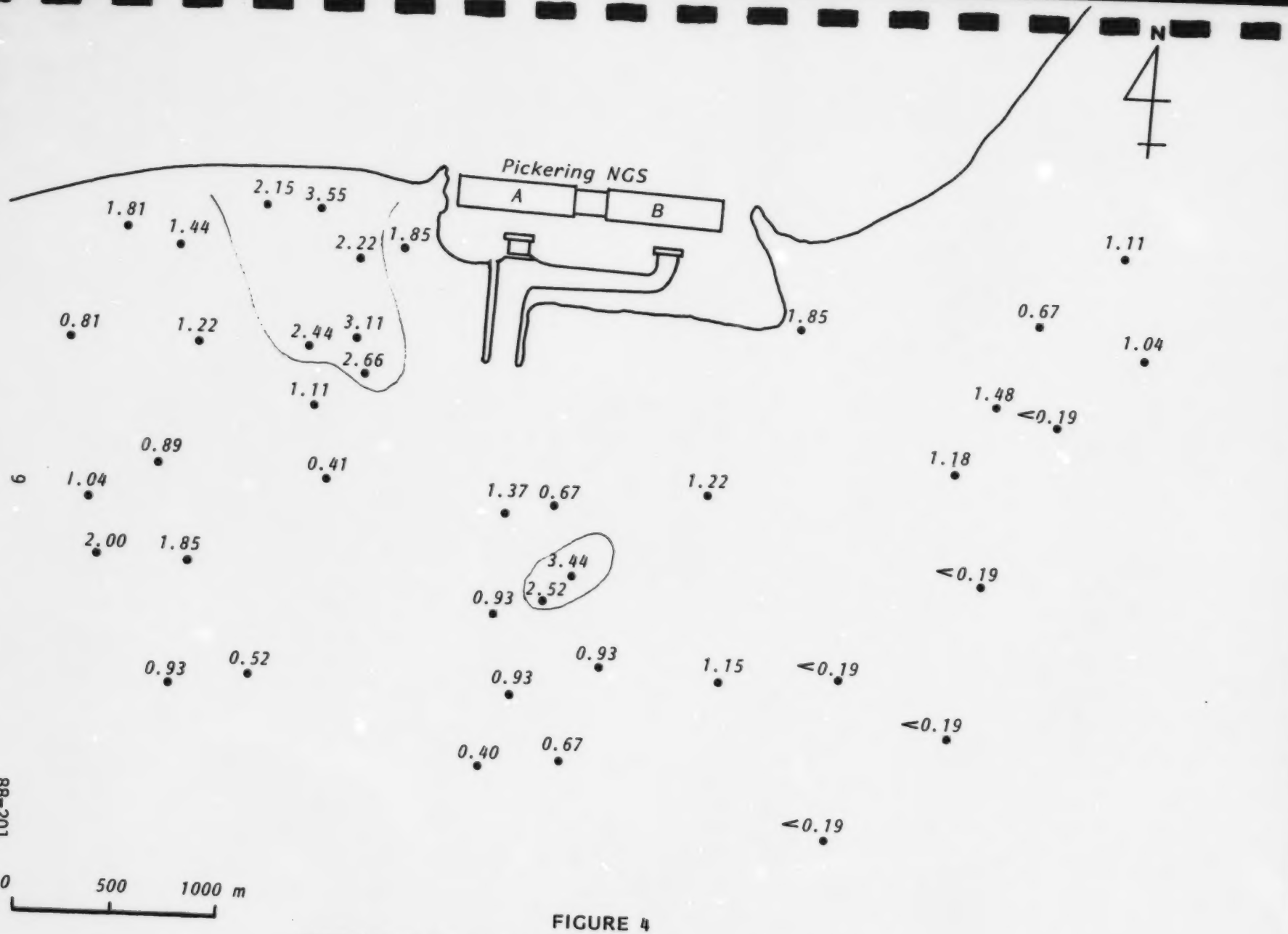

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FIGURE 4

DISTRIBUTION OF COBALT-60 (Bq/kg) IN THE SEDIMENT AROUND PICKERING NGS, PICKERING NGS B POST-OPERATIONAL STUDY, 1987

4.0 DISCUSSION

Surface sediment samples collected along the 3 m depth contour at the Pickering NGS A and B discharges, Duffin Creek and Liverpool Road in 1987, were analyzed for radionuclides by Health and Safety Division of Ontario Hydro (SSD-AR-87-1). Their results indicated levels of ^{134}Cs at the Pickering NGS A discharge (1.1 $\pm$ 0.7 Bq/kg) within the range we obtained for the study area. They did not determine ^{134}Cs levels at the remaining locations.

^{137}Cs levels reported by Health and Safety for the four locations were within the range we obtained. Their highest level of 27 $\pm$ 2 Bq/kg recorded at Liverpool Road was substantially higher than it had been in 1986 (SSD-AR-86-1, 2.6 Bq/kg). Their levels were under 3.5 Bq/kg for the remaining locations.

The ^{60}Co level reported by Health and Safety Division was 1.9 Bq/kg for the Pickering NGS B discharge location and 1.5 Bq/kg for Liverpool Road. These values were within the range obtained at sampling locations included the present study. Health and Safety did not determine in ^{60}Co levels at tne Pickering NGS A discharge and Duffin Creek.

McKinley (OHRD Report No 85-3-K) studied the inshore distribution of gamma radionuclides at the 3, 6, 12 and 20 m depth contours between the Rouge River, west of Pickering NGS, to Raby Head, east of Darlington NGS in 1984. His samples were collected using a ponar grab sampler. Sampling locations that overlapped with those included in the present study were his 3, 6 and 12 m locations along transects at the Pickering NGS A (transect 3) and Pickering NGS B (transect 4) discharges. He did not detect ^{134}Cs at these locations while his mean levels of ^{137}Cs and ^{60}Co were higher than those reported here. Levels of ^{137}Cs were within the range obtained in the present study while the maximum level of ^{60}Co was higher than the maximum value (17.8 Bq/kg) obtained in the present study.

McKinley only detected ^{134}Cs at a single sampling location 22 km east of Pickering NGS. It was detected at a level of 0.6 Bq/kg; a level comparable to the lower range obtained in the present study. Levels of ^{137}Cs were similar throughout his study area. ^{60}Co was only detected at nine locations, two of which were in the vicinity of the Pickering NGS A discharge (3 and 6 m depths). His highest level was detected at the 3 m Pickering NGS A discharge location.

^{134}Cs, ^{37}Cs and ^{60}Co all had areas of highest accumulation just west of the Pickering NGS A discharge. These radionuclides are also products of weapons testing although ^{134}Cs has not been a significant component of fallout (Wrenn et al 1974). Therefore, the major source of this radionuclide in the study area was Pickering NGS. Since the three radionuclides were correlated with each other, the main source and variables affecting their distributions can be expected to be similar. Higher levels of radionuclides in the sediment around nuclear generating stations have been reported for marine environments (Nagaya and Nakamura 1975; Ramberg 1984).

Depth was the main determinant of the distributions of all three radionuclides with levels decreasing with increasing depth. Depth was also found to influence the distributions of ^{137}Cs in McKinley's study, although organic content was the main determinant for both ^{137}Cs and ^{60}Co. Depth in our study is probably related to distance from the source.

The decrease in ^{134}Cs and ^{60}Co levels with distance from shore indicates that the distribution of these two radionuclides is source related suggesting that their distributions are associated with the station discharge. The distribution of ^{137}Cs differed from those of ^{134}Cs and ^{60}Co in that its range was wider and the levels at the higher end occurred in a small area immediately to the west of the Pickering NGS A discharge. In the remainder of the study area levels did not decline with

distance from shore as they did in the cases of ^{134}Cs and ^{60}Co and were substantially lower than in the immediate area of the Pickering NGS A discharge. These differences in its distribution account for the lack of significant correlation with distance from shore. However, since the distribution of ^{137}Cs was correlated with those of ^{134}Cs and ^{60}Co, its source is expected to be similar.

Adsorption is the main sorption process of radionuclides to sand and gravel while ion exchange is the main sorption process to finer grains (Charles and Prime 1983). The levels of ^{134}Cs and ^{137}Cs decreased as the silt content of the sediment increased. Aston and Stanners(1982) found that the silt fraction was important in the distribution of ^{137}Cs which was positively correlated with silt content. Differences in mineral types may account for the different relationship between ^{137}Cs and silt content in the two studies. However, given the relatively small study area included in our study it is more likely that the silt fraction of water entrained through Pickering NGS settles out beyond our offshore limit. The coarser, heavier sand particles, mixed in with the suspended sediments brought in by the along shore currents, settle out in the immediate vicinity of the station. Since the suspended solids entrained through the station rather than the material brought in by the along shore current would be expected to sorb the radionuclides, the relationship described by Aston and Stanners (1982) was not observed.

The distribution of the three radionuclides was source related and decreased with offshore distance from Pickering NGS A. Thus, as hypothesized, chronic release of low levels of ^{134}Cs, ^{137}Cs and ^{60}Co into the water has resulted in areas of higher accumulation in the sediment around Pickering NGS. However, the areas of highest accumulation appear to be limited to the immediate vicinity of the station.

McKinley's data suggested that the distributions of ^{134}Cs and ^{137}Cs were not source related while that of ^{60}Co was associated with the Pickering NGS A discharge. The lack of association of ^{134}Cs and ^{137}Cs with the Pickering NGS A discharge in his study was probably related to differences in sampling intensity. His study included six sampling locations within our study area whereas our study covered 42 sampling locations. ^{134}Cs may not have been detected in his study for the same reason since this radionuclide was not detected in nine of our 42 samples.

^{137}Cs was the only radionuclide detected in the smallmouth bass collected from the Pickering NGS B study area in 1986 and 1987. Levels of ^{137}Cs in Lake Ontario fish were found to be on the decline between 1976 and 1982 (Joshi 1984). The mean level reported for trout at the mouth of the Ganaraska River (near Port Hope) in 1981 was 1.4 Bq/kg wet weight (whole fish). Mean levels reported for trout from Cobourg and Niagara-on-the-lake in 1982 were 1.5 and 1.6 respectively. These levels were comparable to levels reported by Joshi for Lake Ontario fish (1984) and Health and Safety (SSD-AR-86-1 and SSD-AR-87-1) for trout (fillets) collected from the Pickering NGS B study area in 1986 and 1987. The level we detected in smallmouth bass in 1986 was within the range reported by Joshi (1984) and Health and Safety for trout and was higher than levels reported for white sucker and whitefish. The 1987 levels were lower than levels detected by Health and Safety in brown trout, lake trout, perch, sucker and bullhead fillets. Levels reported for the above fish were 1.6-2.0, 0.6-0.7, 1.9, and 1.5 Bq/kg, respectively. Different levels in the various fish could be related to different feeding habits and differences in their ranges of movement.

Although the history (ie previous movements or consequent exposure to the Pickering NGS discharges) of the fish analyzed in this study is unknown, smallmouth bass are assumed to reside in the Pickering discharges for extended periods (OHRD Report in draft). If the above assumption is correct, residence of smallmouth bass in the area of Pickering NGS has not resulted in substantial increases in radionuclide levels in these fish.

5.0 SUMMARY

1. Sediment ^{134}Cs, ^{137}Cs and ^{60}Co levels were comparable to levels reported by Health and Safety Division of Ontario Hydro for the study area. ^{134}Cs levels were not detected at locations within our study area sampled by McKinley in 1984 while ^{137}Cs and ^{60}Co levels reported were higher than ours.

2. The highest concentrations of all three radionuclides were found in an area immediately west of the Pickering NGS A discharge.

3. The levels of ^{134}Cs, ^{137}Cs and ^{60}Co were correlated with each other suggesting a similar source and similar variables affecting their distribution.

4. Multiple regression analyses indicated that depth was the main variable affecting the distribution of the three radionuclides. Their levels decreased with depth, suggesting a decline with distance from Pickering NGS.

5. The distributions of ^{134}Cs, ^{137}Cs, and ^{60}Co were source related and decreased with distance from Pickering NGS. As hypothesized, chronic release of low levels of radionuclides into the water resulted in areas of higher accumulation in the sediment around Pickering NGS. However, these areas appear to be limited to the immediate vicinity of the station.

6. Of the three radionuclides, only ^{137}Cs was detected in smallmouth bass (whole fish). Based on the fish which we examined, levels of these radionuclides in fish from the Pickering area were similar to those in fish from other parts of Lake Ontario and comparable to levels recorded by Health and Safety for trout from the Pickering NGS B study area.

7. It is suggested that the presence of Pickering NGS has not resulted in substantial increases in smallmouth bass radionuclide levels.

ACKNOWLEDGMENT

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